

**MEMORANDUM**

**TO:** Larry Butlien, TRC Windsor  
**FROM:** Gastón Leone, TRC Littleton  
**DATE:** November 17, 2005  
**SUBJECT:** Results of Radiological Flow and Transport Ground Water Modeling to Supplement Chapter 5 of the SMC Decommissioning Plan – Newfield, NJ Facility – Shieldalloy Metallurgical Corporation

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As part of the Decommissioning Plan (Revision 1, October 2005) for the Shieldalloy Metallurgical Corporation (SMC) facility located in Newfield, New Jersey, an On-Site Stabilization and Long-Term Control (LTC) alternative was evaluated for the management of residual radioactive materials. This alternative includes the consolidation and shaping of residual radioactive materials at the SMC facility within a portion of the existing Storage Yard (where the majority of these materials currently reside), the placement of an engineered barrier over the surface of these materials, the establishment of institutional controls, and subsequent long-term maintenance and monitoring of the stabilized materials. The engineered barrier will include soil cover materials, as well as a geomembrane barrier. With on-going maintenance and monitoring, the engineered barrier will prevent precipitation from passing through the cover and underlying radioactive materials, will direct surface runoff away from the capped radioactive materials and will provide a barrier to direct contact with the underlying materials. As a result, no radiological impact on ground water is anticipated.

As part of the dose modeling assessment portion of the Decommissioning Plan, an analysis of radiation doses incurred by hypothetical receptors for a period extending 1,000 years into the future must be assessed. Based on the existing provision of drinking water by a publicly-owned water system, the lack of potable ground water wells within the restricted area of the SMC facility and the long-term effectiveness of the engineered barrier when combined with institutional controls and long-term maintenance and monitoring, ingestion of drinking water was not included as a potential exposure pathway within the Decommissioning Plan's dose modeling assessment. Furthermore, based on existing ground water data collected downgradient of the current Storage Yard (where residual radioactive materials have been stored with no protection against infiltration for over 30 years) licensed radioactivity has not been detected above the USEPA's drinking water standards.

Ground water ingestion is not considered to be a likely or reasonably foreseeable pathway by which hypothetical receptors could incur a radiation dose. Even if all controls fail, negative radiological impacts to ground water quality due to leaching are also unlikely to result in population dose potentials in excess of the USNRC's criteria. To demonstrate this point, TRC developed a numerical ground water flow and transport model to assess a scenario in which the engineered barrier would fail and radionuclides would leach from the stabilized radioactive materials and reach the water table, where they would be subsequently transported by the ground

water. The model was primarily used to assess potential impacts to a hypothetical residential water well located approximately 100 feet downgradient of the Storage Yard. Figure 1 presents the facility layout, including the location of the consolidated radioactive material and the hypothetical water supply well.

The ground water model in the RESRAD computer code is not, in and of itself, applicable to assessing site-specific groundwater impacts from the capped SMC Storage Yard. This is because the model assumes the drinking water well is installed directly on top of the engineered barrier, with ground water drawn from immediately below the location of the licensed radioactivity. Therefore, a supplement to the RESRAD analysis was developed in order to include radionuclide transport at a more realistic well location.

The supplemental model was developed using the numerical code *MODFLOW-SURFACT*, Version 2.2 (HydroGeoLogic Inc., 2002), which is a three-dimensional finite difference code that can simulate ground water flow and transport. *MODFLOW-SURFACT* simulates the following processes for the transport of contaminants in ground water: advection, dispersion, equilibrium adsorption and desorption on soil surfaces, and decay due to radiological transformations.

The following conceptual model and parameter values, taken from Rev. 1 of the SMC Decommissioning Plan unless otherwise noted, were assumed for the analysis of impacts to the water supply well:

1. Radionuclides are leached from the consolidated radioactive materials during infiltration of precipitation following failure of the engineered barrier. Concentrations of radionuclides reaching the water table underneath the consolidated radioactive materials were calculated using the RESRAD model. Four radionuclides reach the water table during the 1,000 year period of analysis: Actinium 227 (Ac-227), Protactinium 231 (Pa-231), Lead 210 (Pb-210), and Radium 226 (Rd-226). The time at which these radionuclides reach the water table was also calculated by the RESRAD model. Figure 2 presents the concentrations calculated by RESRAD for these four radionuclides in leachate reaching the water table. These concentrations correspond to the input parameters provided by Integrated Environmental Management, Inc. (input file: Newfield 300308.rad). This RESRAD simulation assumes a precipitation infiltration rate equal to the natural ground water recharge rate of 10.9 inches per year. The ground water recharge for this area was calculated using the methodology provided by the New Jersey Geological Survey in publication DGS99-2. The assumption that infiltration through the consolidated radioactive materials will equal the natural ground water recharge constitutes a worst case scenario, considering that the pile will have at least a partial engineered cover (i.e., it is highly unlikely that the entire cover would fail at once) and surface runoff will be diverted away from the pile.

2. The shallow aquifer underneath the facility is comprised of two main hydrogeologic units, the Upper Cohansey Sand and the Lower Cohansey Sand. Around the vicinity of the Storage Yard, these two units are separated by a low conductivity clay "wedge" unit ranging from 6 feet to 4 inches thick. There is a significant vertical hydraulic gradient of approximately 0.5% between the Cohansey sands. The Upper Cohansey sand is approximately 40 feet thick and has an average hydraulic conductivity of 200 ft/day. The Lower Cohansey sand varies in thickness between 60 and 80 feet, with an average hydraulic conductivity of 70 ft/day.
3. A constant recharge rate of 10.9 inches/year was applied to the entire model domain.
4. The hypothetical water supply well is located 100 feet downgradient of the Storage Yard along the leading edge of a potential plume, has a depth of 40 feet (screened within the Upper Cohansey sand) and an average pumping rate of 328 gal/day. The pumping rate is based on a household of four people, an average water consumption per capita of 75 gal/day (American Water Works, 2005), and an outdoor water use of 28 gal/day (U.S. Geological Survey, 1977).

The model domain is 2,000 feet long, 1,200 feet wide and 110 feet thick. The model grid has 69 rows, 71 columns, 11 layers, and a total of 53,889 cells. Constant head cells were set all around the model perimeter, with specified heads that correspond to the potentiometry and vertical gradients of each sand.

A steady state flow calibration was conducted using water levels measured on October 12, 1992. On this date, ground water remediation pumping was discontinued in order to obtain ambient flow conditions representative of steady state flow within the aquifer. The average hydraulic conductivity values of 200 and 70 ft/day for the Upper and Lower Cohansey sands were used during the steady state calibration. Figures 3 and 4 present the results of the calibrated water levels for the Upper and Lower Cohansey sands. The simulated ground water flow direction is to the southwest with an average gradient of 0.002 ft/ft in both sands. Calibration results indicate a good fit between model simulated and measured ground water levels, with a root mean square (RMS) error of 0.48 feet. The ratio between the RMS and the hydraulic head change across the model domain (3.5 feet) is 13.7%.

After the model calibration was completed, a predictive solute transport simulation was conducted. This predictive simulation consisted of applying the RESRAD transient concentrations presented in Figure 2 at the water table over the entire area underneath the consolidated residual radioactive materials at a leaching rate equal to 10.9 inch/year. Chain decay was not explicitly simulated because the effect of the progeny was considered negligible. Transport of each radionuclide was evaluated independently. This simulation also included pumping from the hypothetical water supply well indicated in Figure 1. Table 1 presents the solute transport parameters used in this simulation.

Table 1 – Solute Transport Parameters

Parameter	Units	Value
Longitudinal Dispersivity	ft	30
Horizontal Dispersivity	ft	3
Vertical Dispersivity	ft	0.3
Effective Porosity	unitless	0.25
Kd – Ac-227	mL/gr	20
Kd – Pa-231	mL/gr	50
Kd – Pb-210	mL/gr	100
Kd – Ra-226	mL/gr	48
Half-life – Ac-227	Year	21.7
Half-life – Pa-231	Year	32,760
Half-life – Pb-210	Year	22.8
Half-life – Ra-226	Year	1,600

The porosity value is the same as the effective porosity used for the RESRAD simulation and is within the range of typical values for this type of aquifer material. Dispersivity values were estimated assuming a 300-foot plume length and following Pickens and Grisak guidelines for dispersivity estimates (Pickens and Grisak, 1981). The 30-foot longitudinal dispersivity value is very conservative given the 100-foot travel distance to the hypothetical water well. The distribution coefficient (Kd) value for Ra-226 is a site-specific value measured for the residual radioactive materials which is not necessarily representative of the Kd value for the aquifer materials. This value was used because it is conservative with respect to the default value of 70 mL/gr that is commonly accepted as applicable for Ra-226. The remaining Kd values are defaults used in RESRAD. Half-life values were obtained from the RESRAD database.

Figure 5 presents the model calculated concentrations of radionuclides at the water supply well located 100 feet downgradient from the Storage Yard. The solute transport modeling results indicate that after 1,000 years the Ra-226 concentration will reach a maximum of 3.43 pCi/L, while Ac-227 will reach 0.22 pCi/L. The Pb-210 and Pa-231 concentrations remain at or below 0.05 pCi/L. Concentrations at this well remain relatively low during the 1,000 year time period due to the dilution that takes place within the aquifer and the significant retardation of these radionuclides. Table 2 presents the maximum annual dose in the hypothetical water supply well at year 1,000 based on the maximum concentrations calculated with the solute transport model. The water consumption rate and dose conversion factors are default values used in RESRAD.

Table 2 – Maximum Annual Dose Associated with a Water Supply Well at Year 1,000

Radionuclide	Water Consumption Rate (L/Year)	Dose Conversion Factor for Ingestion (mrem/pCi)	Maximum Concentration (pCi/L)	Dose (mrem/Year)
Ac-227	410	0.0148	0.22	1.33
Pa-231	410	0.0106	0.05	0.20
Pb-210	410	0.00727	0.00	0.00
Ra-226	410	0.00133	3.43	1.87
Total Dose				3.40

A sensitivity analysis was conducted to identify the key parameters that control the maximum dose simulated at the hypothetical water supply well. A total of four parameters were considered in this sensitivity analysis: hydraulic conductivity, effective porosity, dispersivity, and distribution coefficients for Ac-227 and Ra-226. Only Ac-227 and Ra-226 were considered as part of the distribution coefficient sensitivity analysis because these two radionuclides provide the majority of the dose at the water supply well. Two sensitivity simulations were conducted for each of the identified parameters. Each parameter value, except for effective porosity, was increased for the first simulation by a factor of 2 (100% increase) and then decreased by a factor of 2 (50% decrease) for the second simulation. A sensitivity factor of 1.5 (50% increase and 33% decrease) was used for effective porosity in order to keep this parameter value within the literature range for the type of materials in the Cohansey sands.

Table 3 presents the results of the sensitivity analysis. This table shows the maximum calculated dose at the water supply well and also the relative percent change with respect to the base case total dose of 3.40 mrem/year presented in Table 2. The maximum calculated dose for all sensitivity scenarios is 17.10 mrem/year. This sensitivity analysis shows that the dose is insensitive to changes in effective porosity and moderately sensitive to dispersivity. The results are highly sensitive to decreases in distribution coefficients and changes in hydraulic conductivity.

Table 3 – Sensitivity Analysis Results

Parameter	Initial Value	Sensitivity Factor (%)	Maximum Dose (mrem/year)	Dose Sensitivity Factor (%)
Hydraulic Conductivity	200 ft/d U Cohansey	100	12.04	254
	70 ft/d L Cohansey	-50	0.51	-85
Effective Porosity	0.25	50	3.38	-1
		-33	3.42	0
Dispersivity (Long., Horiz., Vertical )	30 ft, 3 ft, 0.3 ft	100	5.23	54
		-50	2.27	-33
Kd – Ra-226	48 mL/gr	100	1.62	-52
		-50	17.10	357
Kd – Ac-227	20 mL/gr	100	2.19	-36
		-50	10.21	200

## Attachments:

Figure 1 – Site Layout and Model Domain

Figure 2 – Radionuclides in Leachate Reaching the Water Table – RESRAD Model

Figure 3 – Upper Cohansey - Steady State Potentiometry

Figure 4 – Lower Cohansey - Steady State Potentiometry

Figure 5 – Radionuclides in Water Supply Well

## References:

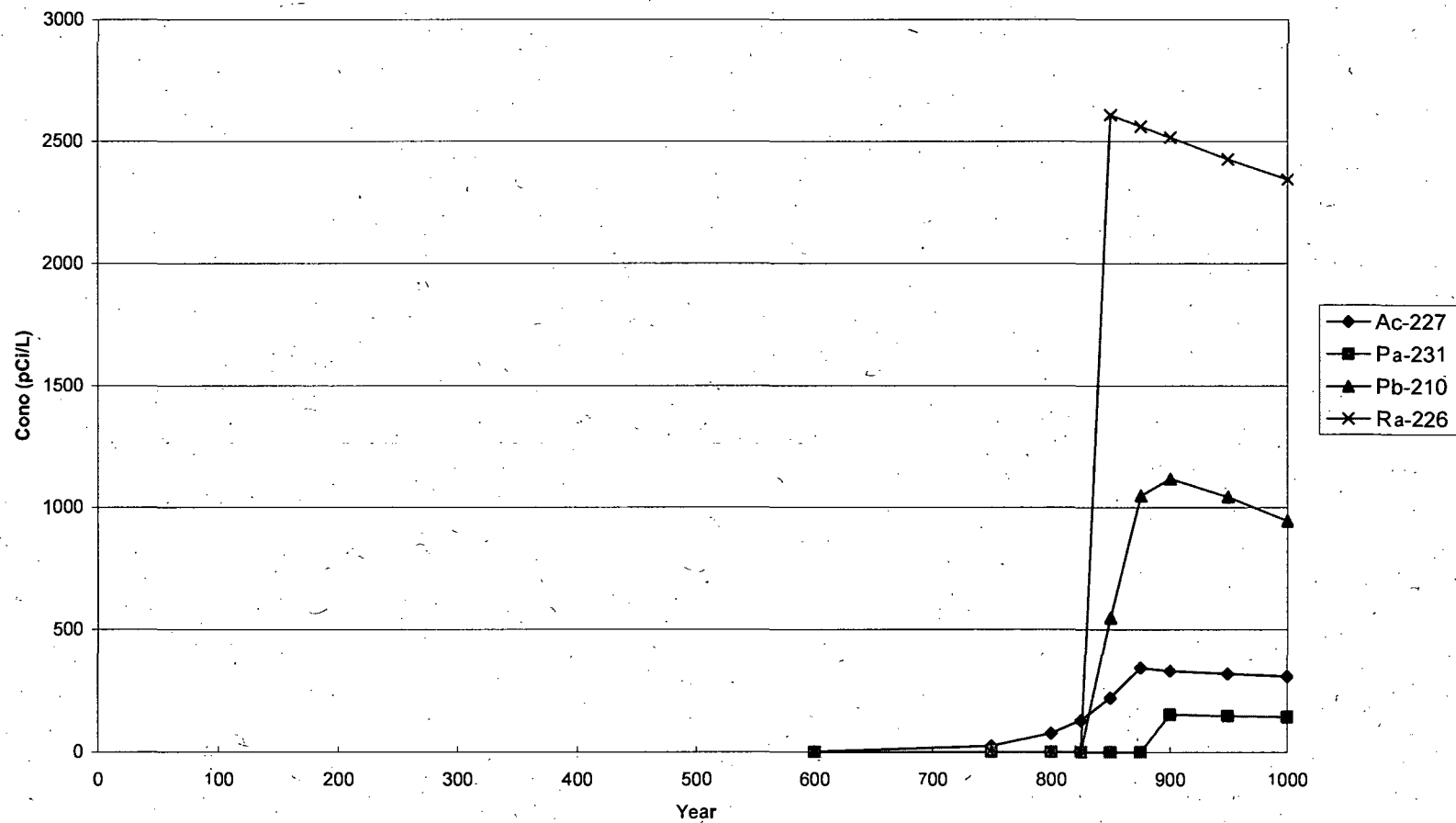
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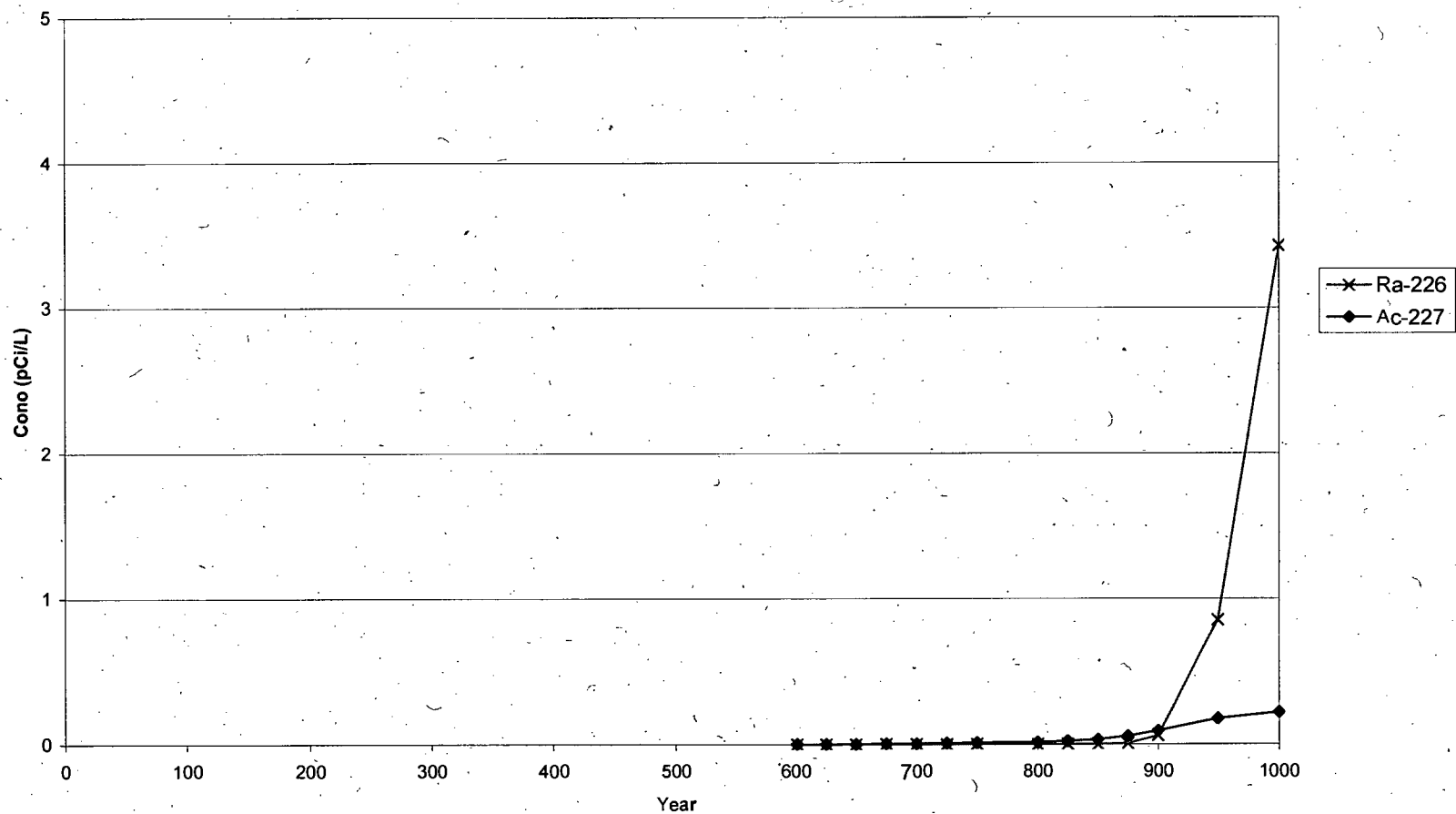


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FIGURE 2: Radionuclides in Leachate Reaching the Water Table RESRAD Model				
<b>TRC</b>	DATE	PROJECT	CAD ID	REVISION
	10/10/2005	26770	MD01	3









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FIGURE 5:  
Radionuclides in Water Supply Well

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	10/10/2005	26770	FIG5	3

#### Appendix 19.4 - Distribution Coefficients and Leachability